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Dune vegetation of the Swan Coastal Plain, Western Australia

by I. D. Cresswell* and P. B. Bridgewater**
School of Environmental & Life Sciences, Murdoch University, Perth, W.A.
*Now at—Division of Groundwater Research, CSIRO, Wembley, W.A.
**Now at—Bureau of Flora and Fauna, Canberra, A.C.T.

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Abstract

A study of vegetation on the aeolian deposits of the Swan Coastal Plain, using classification techniques, revealed 49 vegetation units. These units were agglomerated into plant communities and complexes, on the basis of floristic composition. A Conspectus to the vegetation classification is provided.

Vegetation in this region is generally considered to be species-rich. Vegetation on the oldest (Bassendean) dune system was most species-rich. The complexity of vegetation pattern (vegetation texture) was greatest on the intermediate aged (Spearwood) dune system. Vegetation on the Quindalup dune system was both species-poor and had the simplest texture relative to the other two dune systems.

It is postulated that species-richness and vegetation texture change dynamically through time, as the dune systems become more stabilised and leached.

A key to the described communities is provided to allow researchers, conservation managers, teachers and other interested persons to allocate vegetation of particular bushland sites to a plant community described in the Conspectus, and thus increase knowledge of the vegetation variation in bushland remnants across this region.

Introduction

Much of the work on vegetation description in Western Australia has used a structural or physiognomic approach, e.g. Diels (1906), Speck (1952), Seddon (1972). Recent work (e.g. Heddle (1979), Heddle *et al.* (1980)) utilised floristic attributes, within a structural framework, based on the work of Havel (1968) who invoked the concept of site-vegetation types using a quantitive ordination-type approach to the analysis of floristically based data.

Heddle (1979) emphasised what she saw as a confusion of vegetation pattern, caused by the apparently continuous nature of vegetation change. She states:

> "For the vast majority of the area investigated in the Perth Region the pattern of vegetation has been detected on the localized scale but not over larger areas. Possibly one of the reasons was the difficulty encountered by earlier workers in classifying large areas of vegetation. This was due to the fact that the vegetation is a complex, predominantly continuous population pattern, with both individual species and groups of species having dissimilar distribution patterns, vegetation in the field being consequently mixtures in varying proportions of continuity and discontinuity. This multi-dimensional nature of the vegetation is by no means a feature unique to Western Australia."

We believe that vegetation of the Swan Coastal Plain (Fig. 1) is amenable to treatment by classificatory techniques; the sharply changing nature of the soil systems and a highly seasonal climate are environmental controls which favour sharp, rather than diffuse, boundaries in vegetation.

The very high species richness of the Coastal Plain vegetation can, however, obscure these boundaries and produce an illusion of vegetation complexity. A great many species occur spasmodically in space and time, reacting to seasonal perturbations and irregular environmental features such as fire. Other reasons for high species-richness are advanced by Lamont *et al.* (1984). Previous work by Bridgewater (1982) showed that a classification strategy could be used successfully in this vegetation, and the late Prof R. Tüxen *(pers. com.)* remarked, on seeing some of the raw data from this study, that this must surely be one of the best areas in the world to apply classification techniques!

Methods and results

(a) Data collection and analysis

In the present study, over 400 separate samples of vegetation were collected from about 100 sites on the aeolian derived dune systems of the Swan Coastal Plain (Fig. 1). Each sample was a quadrat of 10 m^2, from which all vascular plant species were listed. Each species was allocated a value on the Braun-Blanquet (1964) cover/abundance scale.

As an anonymous reviewer indicated, choice of any technique is largely a matter of convenience and purpose, a point with which we concur. In the present study we have opted for a classification technique, with the aim of identifying and clarifying the main vegetation variation, despite the apparent confusion caused by high levels of species richness.

Initially vegetation samples were allocated to groups using the cluster analysis technique of Carlson (1972). These were then further refined using computer program VEGCLASS (Bridgewater and Morales, 1982). VEGCLASS is a computer-aided system of tabular synthesis, which simplifies analysis of large data sets. These analyses revealed 49 vegetation units, which were arranged in a hierarchical classification based on floristic relationships, following the *schema* used by Pen (1983). Details of these vegetation units appear in the following conspectus, and full floristic tables are included in Cresswell (1982). Vegetation from Rottnest Island, and other offshore islands, has some special features which are not treated in this paper.

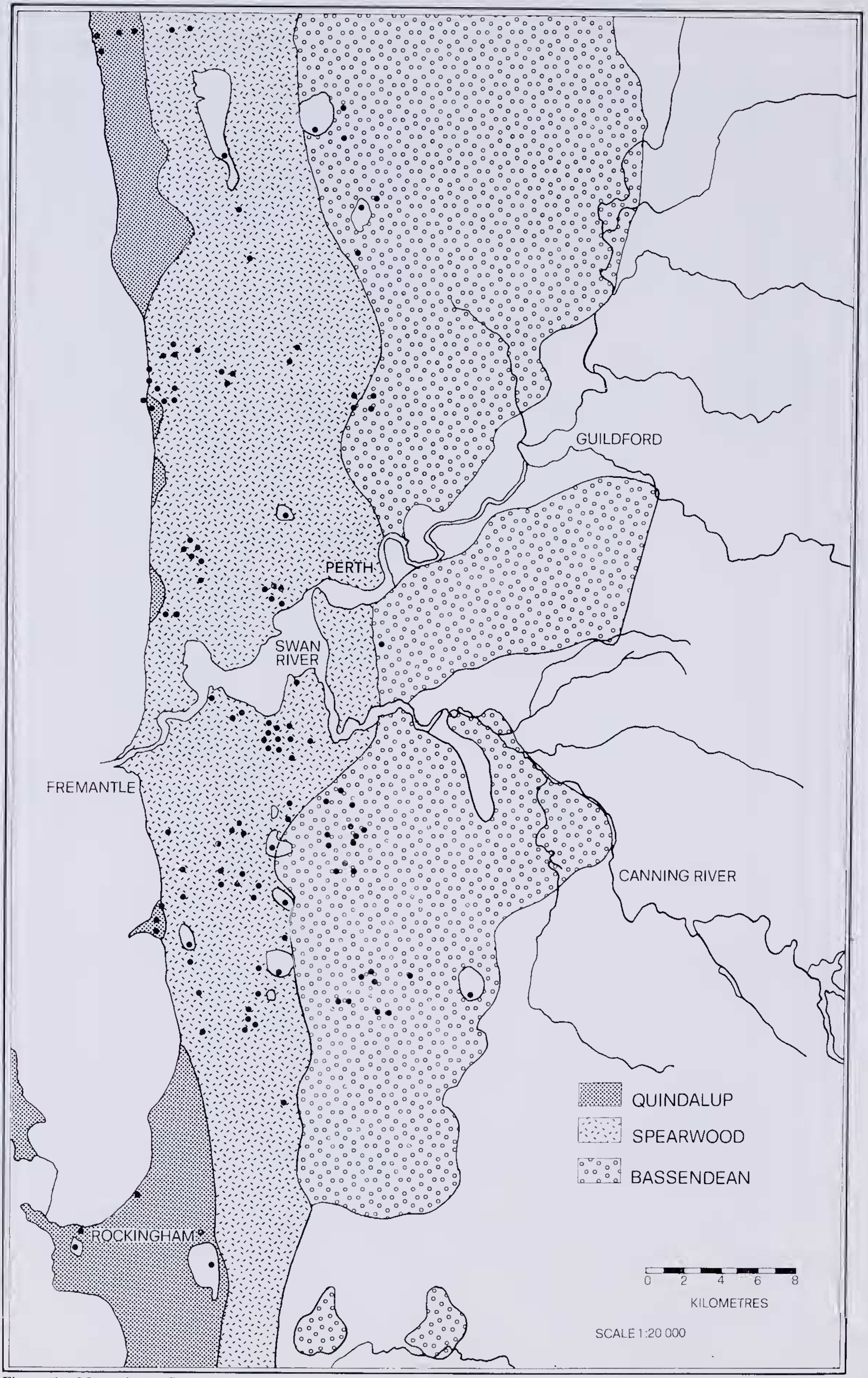

Figure 1.—Map of the Swan Coastal Plain, showing sample sites (•), and the boundaries of aeolian deposits.

(b) Conspectus of vegetation units

Vegetation units identifed in the study are described in this section, from floristic and structural viewpoints. A key to the vegetation units is included as an appendix. This key should enable workers in the field to identify particular vegetation sites within the region described.

The base unit in the hierarchy is the community, analagous to the association of the Zürich-Montpellier System (Bridgewater 1981). Communities are divided into sub-communities and variants, and aggregated to form complexes. In most cases sub-communities are named after a distinguishing species. Where a sub-community has the same species complement as that for the community the epithet "typical" is used. Use of the community-complex nomenclature follows that of Pen (1983) and should not be confused with the use of complex by Heddle *et al.* (1980).

For the lowest level of hierarchical division some distributional and ecological notes are included. Distribution of the vegetation units across the Swan Coastal Plain is shown in Figure 2. Species nomenclature is that of Marchant (in prep.). Specimens of most species named are lodged with the Western Australian Herbarium. Terminology of the geomorphic units used in the text follow Bettenay *et al.* (1960).

Tables 1-3 are summaries of species occurrences in the vegetation units. Identifying species for each unit are those with presences of 4 or 5 in each table. Tables 4 and 5 summarise the congruence between these vegetation units and the structural formations of Specht *et al.* (1974).

A. *Stirlingia latifolia—Oxylobium capitatum* complex

A.1. *Dasypogon bromeliifolius—Lyginia barbata* community

A.1.a. *Scaevola paludosa* sub-community

A.1.a.i. *Monotaxis grandiflora* variant

Usually restricted to the tops of dune ridges in the Karrakatta soil association. Occasionally *Xylomelum occidentale* occurs as extensive patches, more or less replacing *Banksia* species as dominants.

A.1.a.ii. *Acacia willdenowiana* variant

Localised on dune slopes at the junction between Karrakatta and Bassendean soil associations.

A.1.b. *Hardenbergia comptoniana* sub-community

A.1.b.i. *Leucopogon propinquus* variant

Localised on the upper slopes of dune ridges in the eastern sector of the Karrakatta soil association.

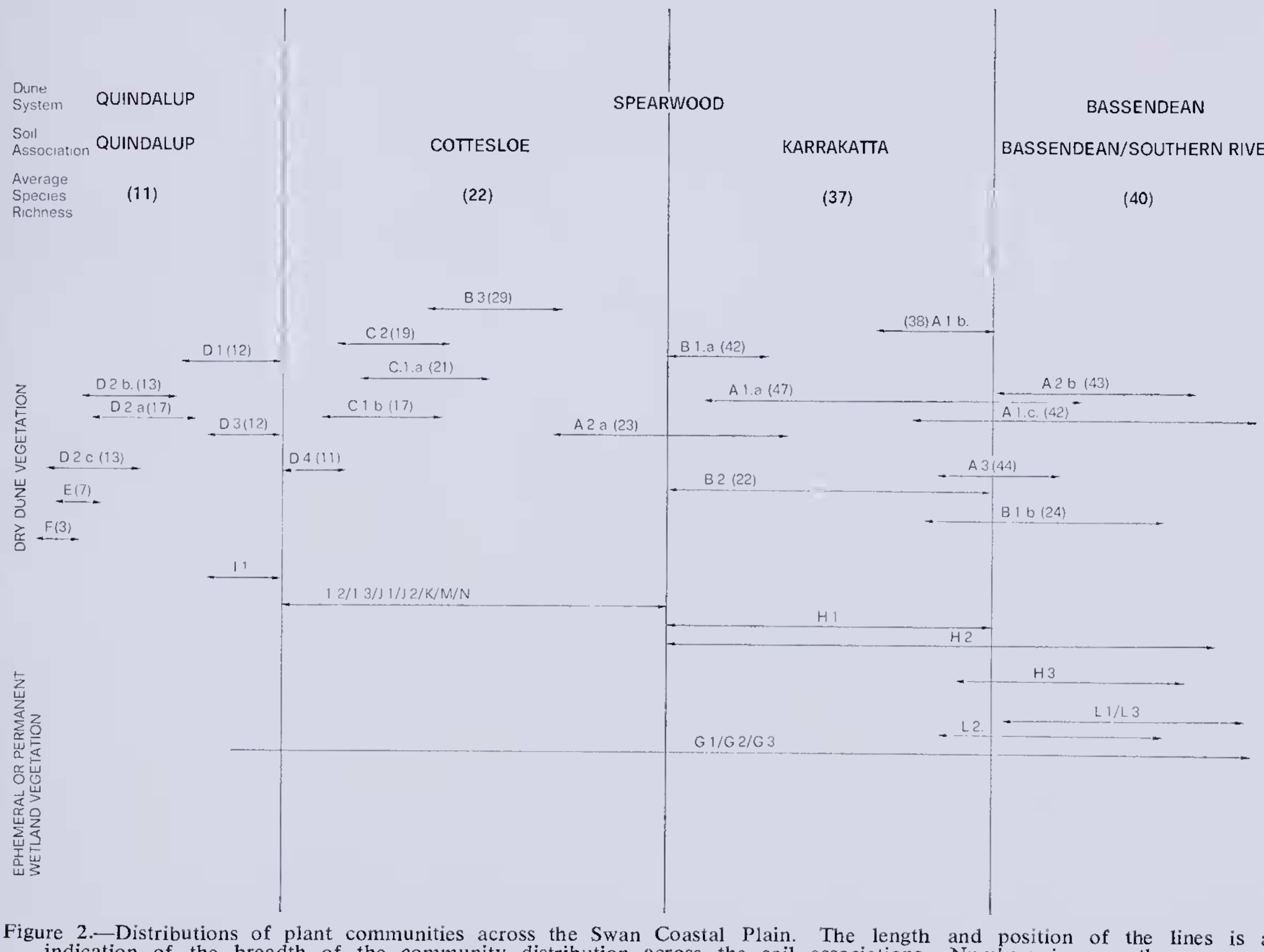

Figure 2.—Distributions of plant communities across the Swan Coastal Plain. The length and position of the lines is an indication of the breadth of the community distribution across the soil associations. Numbers in parentheses are the average species richness for vegetation samples which make up the communities.

A.1.b.ii. *Allocasuarina fraseriana* variant

Common on dune slopes of the Karrakatta soil association.

A.1.c. *Patersonia occidentalis* community

Restricted to swales and lower dune slope in the Bassendean, Southern River and eastern Karrakatta soil associations. Excessive disturbance to this community by mechanical activity can cause a shrub community dominated by *Adenanthos cygnorum* to develop. Many road cuttings and housing developments in the eastern Bassendean system clearly show this.

A.2. *Allocasuarina humilis—Synaphea spinulosa* community

A.2.a. *Acacia pulchella—Conostephium pendulum* sub-community

Localised on dune slopes of the Cottesloe and Karrakatta soil associations.

A.2.b. *Scholtzia involucrata—Banksia ilicifolia* sub-community

Lower dune slopes throughout the Bassendean soil associations, primarily found on slopes verging on ephemeral wetlands.

A.3. *Jacksonia sternbergiana—Pimelea rosea* community

Common on dune slopes of the eastern Karrakatta and western Bassendean soil association. Where this community abuts wetlands a transitional vegetation frequently occurs, with *Eucalyptus rudis* as the tree layer, and *Jacksonia furcellata, Lechenaultia biloba* and, at Thompsons Lake, *Dodonaea hackettiana* common in the shrub layer. The width of this transitional band depends on the slope of the dune—being most extensive where gently sloping dunes grade into wetland.

B. *Xanthorrhoea preissii—Mesomelaena stygia* complex

B.1. *Allocasuarina fraseriana—Hardenbergia comptoniana* community

B.1.a. *Leucopogon propinquus* sub-community

Common on upper slopes in the western Karrakatta soil association. This sub-community includes *Eucalyptus gomphocephala* open-forest, and is frequently degraded, with many exotic species present. Degraded stands of this sub-community often key out as B.2. *Banksia grandis* is an occasional component of the tree layer in this and the next sub-community.

B.1.b. *Alexgeorgea arenicola* sub-community

Localised on the lower slopes of the eastern Karrakatta soil association, and western Bassendean soil association.

B.2. *Dianella revoluta—Mesomelaena stygia* community

Found throughout the Karrakatta soil association. Typically species poor, possibly due to extensive physical and environmental disturbance. The number of exotic species is greater in this sub-community than in any other vegetation unit. As such, it forms a synthetic plant community (Backshall & Bridgewater (1981)) which may be transitional in nature, or represent new metastable vegetation.

B.3. *Dryandra nivea—Lechenaultia linarioides* community

Occurs on ridge topes in the Cottesloe soil association, with limestone cap rock slightly exposed, or near to the surface. In some localities *Agonis flexuosa* occurs in the tree layer.

C. *Dryandra sessilis—Calothamnus quadrifidus* complex

C.1. *Dryandra nivea—Phyllanthus calycinus* community

C.1.a. *Hakea prostrata* sub-community

Confined to the western parts of Cottesloe soil association, on shallow soils with large proportion of limestone rock outcrop. This community is synonymous with the Dryandro-Calothamnetum haketosum (Bridgewater and Zammit (1979)). Exposed outcrops frequently have *Acacia cochlearis, A. lasiocarpa* and *Melaleuca huegelii* as the dominant species.

C.1.b. *Templetonia retusa* sub-community

Found in area frequently subject to seaspray on shallow soils of the Cottesloe soil association; typically limestone outcrops present. This sub-community is synonymous with the Dryandro-Calothamnetum templetonietosum (Bridgewater and Zammit (1979)).

C.2. *Olearia axillaris—Rhagodia baccata* community

Summit of dune ridges, typically with exposed limestone cap-rock, in the extreme west of the Cottesloe soil association.

D. *Olearia axillaris—Rhagodia baccata* complex

D.1. *Callitris preissii* community

Confined to the Quindalup soil association. This community was formerly common along the coast, but is now depleted in area and in floristic quality, due both to urban development and greater fire frequency.

D.2. *Lepidosperma gladiatum* community

D.2.a. *Acacia xanthina* sub-community

Common on dune ridges and upper slopes of the Quindalup soil association, occurring occasionally in deep gullies with a scattered overstorey of *Eucalyptus gomphocephala,* and shrubby *Agonis flexosa* (e.g. at City Beach). Localised on the edges of limestone cliffs in the Cottesloe soil association.

D.2.b. *Acacia cyclops* sub-community

Occurs on the eastern slopes of fore-dunes formed by the Quindalup soil association (referred to as the "youngest" phase by Bettenay *et al.* (1960). As with the previous sub-community, *Agonis flexuosa* may be a component of mature stands of the sub-community.

D.2.c. *Acacia rostellifera* community

Best developed on low ridges of the more exposed areas of the Quindalup soil association.

D.3. *Eucalyptus gomphocephala* community

Confined to sheltered depressions of the Quindalup soil association, becoming more frequent south of Rockingham. This unit is floristically unrelated to the *Eucalyptus gomphocephala* alliance (Specht *et al.* (1974)) of the Cottesloe soil association, which is included under B.1.a.

D.4. *Threlkeldia diffusa—Frankenia pauciflora* community

Confined to exposed limestone cliffs of the Cottesloe soil association, and subject to seaspray. In the north of the region *Nitraria billardieri* and *Melaleuca cardiophylla* occur as components of the community.

E. *Tetragonia implexicoma* complex

E.1. *Tetragonia implexicoma* community

Confined to upper slopes and ridges of the Quindalup fore-dunes.

F. *Cakile maritima* complex

F.1. *Cakile maritima* community

The most seaward of dune vegetation, occuping the strandline of the Quindalup dune system. This community is remarkable because two of its three identifying species are regarded as introductions to Australia *(C. maritima* and *Arctotheca populifolia).* It must also be regarded as a synthetic community, with European man both enabling species vagility, and creating appropriate environmental conditions.

The remaining vegetation units are all from wetland vegetation. Riverine vegetation, associated with the Swan and Canning rivers, is not covered in this account, as Pen (1983) has a detailed review of such vegetation. Where vegetation units described below also occur in riverine systems, they are cross-referenced to Pen (op. cit.). *Occasionally units defined by Pen as "complexes" have been reduced to community status, by the inclusion of material from this wider study. Communities restricted to tidal marshes along river margins are not included in this present account, and the reader is referred to Pen* (op. cit.) *for details.*

G. *Typha-Baumea* complex.

G.1. *Typha orientalis* community

Identified by the dominance of *T. orientalis* and presence of few other species. Widespread throughout lentic wetlands and in riverine situations, but absent from the most saline sites.

G.2. *Typha orientalis—Baumea articulata* community

Identified by the co-dominance of the two naming species, and presence of few other species. Possibly a short-lived dynamic phase transitional from the *Baumea articulata* community to the *Typha orientalis* community.

G.3. *Baumea articulata* community

Identified by the dominance of *B. articulata,* and presence of few other species, this community is found only in freshwater sites. In the majority of the areas where it occurs there is evidence of invasion by *Typha orientalis.* Disturbance, eutrophication and changes to wetland water levels (both raising and lowering) all appear to facilitate this invasion.

H. *Melaleuca rhaphiophylla* complex

H.1. *Schoenoplectus validus* community

Identified by the dominance of *S. validus* with *Polygonum salicifolium* as a prominent understory species. Typically occurs as fringing vegetation of lakes in the Karrakatta soil association. Severely degraded or exposed sites may be species poor, with *S. validus* being dominant, *M. rhaphiophylla* infrequent and few other species present. *Phyla nodiflora* is abundant in such sites, as a ground cover.

H.1.a. typical sub-community

This sub-community occurs in swamps, often with a permanent water table above soil level, and in thin zones along the upper reaches of the major rivers, where it is expressed as monospecific stands of *Schoenopletus* (Pen 1983).

H.1.b. *Carex fascicularis* sub-community

Identified by an abundance of *C. fascicularis* in the lower sedge stratum. Localised as vegetation fringing lakes, particularly abundant in the northern sector of the study area.

H.2. *Melaleuca rhaphiophylla—Eucalyptus rudis* community

Widely distributed throughhout the Karrakatta and Bassendean soil associations. The three sub-communities represent a transition from semi-open water (H.2.a.) to dry soil surface (H.2.c.) Pen (1983) defines a *Eucalyptus—Melaleuca Complex,* which would form part of this community, defined in the broader terms of the whole coastal plain.

H.2.a. *Polygonum salicifolium* sub-community

P. salicifolium is present as the dominant understory species, typically submerged or floating in open water at the edge of lakes and swamps.

H.2.b. *Centella asiatica* sub-community

C. asiatica is present as the major understorey species. The sites occupied by this sub-community are ephemeral winter swamps.

H.2.c. *typical* sub-community

This sub-community is found on the driest sites around lakes.

H.3. *Melaleuca rhaphiophylla* community

Identified by the dominance of *M. rhaphiophylla* with few other species present. Structurally this community is a tree overstorey on open water. In some sites *Lemna* spp. occur as floating aquatics on the water surface.

I. *Juncus kraussii* complex

I.1. *Centella asiatica* community

Identified by the dominance of *Baumea juncea,* with *C. asiatica* the major understory species. This is a very restricted community, apparently confined to wetlands in the Quindalup soil association.

I.2. *Juncus kraussii* community

Restricted to wetlands whose waters have relatively high conductivities. This community appears as a brackish water vicariant to the *Baumea articulata* community. Also frequent along the rivers upstream from the Narrows—termed *Melaleuca-Juncus* Complex by Pen (1983).

I.2.a. *typical* sub-community

I.2.b. *Melaleuca rhaphiophylla* sub-community

In some localities *Melaleuca rhaphiophylla* is present as an overstorey species, and such vegetation has been called the *Melaleuca rhaphiophylla* sub-community. The typical sub-community lacks the overstorey. This is a particular example of vegetation nomenclature where importance is placed on the lower stratum being of greater environmental indicator value than the upper stratum.

I.3. *Melaleuca rhaphiophylla—Baumea juncea* community

I.3.a. *Juncus kraussii* sub-community

J. kraussii and *B. juncea* are co-dominant in the understorey, with few other species present. This sub-community is closest to the waterline.

I.3.b. *Aster subulatus* sub-community

A. subulatus and *Cotula coronopifolia* are constantly present in the understorey, typically with a number of other ephemeral species. This sub-community occurs landward of I.3.a.

I.3.c. *Melaleuca teretifolia* sub-community

M. terefolia is present as co-dominant with *M. rhaphiophylla,* with *Ruppia polycarpa* and *Chara* spp. (Charophyta: Algae) occurring as submerged macrophytes in open water amongst the *B. juncea* layer. Occurs only south of the Swan River.

I.3.d. *typical* sub-community

This species-poor sub-community occurs occasionally within the study area.

J. *Sarcocornia quinqueflora* complex

J.1. *Sarcocornia quinqueflora* community

Identified by the dominance of *S. quinqueflora* and the occasional presence of *Suaeda australis* and/or *Samolus* spp. Restricted to the most westerly wetlands, this community is typically associated with estuarine salt marshes, and occurs extensively along the fringes of the Swan and Canning Rivers, as well as in lentic wetlands. Equivalent to the *Sarcocornia* Community (Pen 1983).

J.2. *Juncus kraussii—Sarcocornia quinqueflora* community

Confined to the western-most lakes, presumably influenced by sea spray drift, as well as high levels of solutes from surface limestone rock. Also in saltmarshes along the lower reaches of the rivers. Equivalent to the *Juncus* typical Community (Pen, 1983).

J.2.a. *Suaeda australis—Samolus* spp. sub-community

Suaeda australis, Samolus repens and *Samolus junceus* are present as co-dominants in the understorey. Usually found in standing water at lake edges.

J.2.b. *Melaleuca rhaphiophylla* sub-community

M. rhaphiophylla is present as an overstorey, with *J. kraussii* and *Gahnia trifida* present as co-dominants in the understorey. This sub-community is found in empheral swamps, and up-shore of H.2.a. in lakes.

K. *Melaleuca cuticularis* complex

Identified by the dominance of *M. cuticularis* with the presence of few other species. This community is confined to wetlands where waters have very high conductivities (>25 mho/cm in winter). Also represented in small relict patches along the shore of Melville Water, as the *Juncus-Melaleuca* Community of Pen (1983).

L. *Lepidosperma longitudinale* complex

L.1. *Melaleuca teretifolia—Lepidosperma longitudinale* community

This is one of three communities which are of importance in separating the wetlands in the south of the study area from those of the north, being abundant in ephemeral wetlands in the Bassendean soil association.

L.2. *Viminaria juncea* community

This community forms dense thickets at the extreme littoral fringe of fresh water lakes and swamps.

L.3. *Astartea fascicularis—Schoenus subfascicularis* community

Restricted to ephemeral wetlands recharged during winter from ground water flows and surface water seepage in the Bassendean soil association.

L.3.a. *Banksia littoralis—Melaleuca preissiana* sub-community

B. littoralis and *M. preissiana* are present as co-dominant tree species over a species-rich understorey. There are a number of variants of this sub-community, which require further study before their status can be established.

L.3.b. *Eutaxia virgata* sub-community

E. virgata is present in a species-poor shrubland, with no trees present.

M. *Bulboschoenus caldwellii* complex

M.1. *Bulboschoenus caldwellii* community

Confined to areas of standing water in the western-most brackish swamps. Two *Chara* species and *Ruppia polycarpa* are present as submerged macrophytes in this community, which is the only community of the complex. Clearly related to the *Bulboschoenus* Community of Pen (1983), which lacks submerged macrophytes, perhaps because of more rapid water movement.

N. *Melaleuca teretifolia* complex

N.1. *Melaleuca teretifolia* community

Identified by the dominance of *M. teretifolia* with the presence of few other species. Like the *M. teretifolia—Lepidosperma longitudinale* complex, this is confined to the southern sector of the study area, and has only one component community.

O. *Polypogon monspeliensis* complex

The identifying species is an exotic grass, which underlies the major feature of all quadrats allocated to this complex—they all suffer from gross physical disturbance, and are best regarded as degraded variants of some of the previously described communities.

Table 1

Summary table of the major species composition of vegetation units from the *Stirlingia latifolia—Oxylobium capitatum* complex (A), and the *Xanthorrhoea preissii—Mesomelaena stygia* complex (B). Numerical values in the table indicate the percentage occurrence of the species in the quadrats sampled for the respective vegetative unit, as follows:

1. species present in 1-9% of the samples
2. species present in 20-39% of the samples
3. species present in 40-59% of the samples
4. species present in 60-79% of the samples
5. species present in 80-100% of the samples

Complex code:	A	A	A	A	A	A	A	A	B	B	B	B
Association code:	1	1	1	1	1	2	2	3	1	1	2	3
Sub-Association code:	a	a	b	b	c	a	b		a	b		
Variant code:	i	ii	i	ii								
Number of samples:	5	3	12	8	30	5	6	3	13	6	8	4
Species												
Banksia attenuata	3	5	4	5	5	5	5	4	5	5	3	2
Hibbertia hypericoides	5	5	5	5	4	5	5	5	5	4	3	4
Gompholobium tomentosum	4	5	3	3	4	5	5	4	4	4	3	3
Banksia menziesii		5	3	3	5	5	5	5	4	4	2	
Xanthorrhoea preissii	4	5	5	4	2	3	2	4	4	5	2	5
Macrozamia riedlei	3	2	5	4	2	3	2	5	5	5	2	3
Burchardia umbellata	5	5	5	4	5	2	5	5	5	2	4	2
Mesomelaena stygia	5	5	3	2	2	5	4	4	4		4	5
Stirlingia latifolia	4	4	2	4	4	3	4	5	1		1	
Petrophile linearis	5	2	4	4	5	3	5	4	4	2	1	
Diplopogon setaceus	5	2	1	2	4	4	4	5	1		1	2
Hypocalymma robustum	5	5	4	4	3	2	4	5	4		1	
Oxylobium capitatum	4	5	3	3	2	2	5	5	3			
Daviesia triflora (M. Crisp *inedit*)	5	5	3	4	4	4	1		3	1	2	
Conostephium pendulum	3	5	3	2	4	5	2		1		1	
Lyginia barbata	3	5	3	2	4		5		2			
Dasypogon bromeliifolius	5	5	2	3	4		2	5	2			
Drosera macrantha	5	5	5	4	3						2	
Lepidosperma angustatum	5	2	4	4	3						2	
Tetraria octandra	3	4	5	4		2		2	3		2	
Isotropis cuneifolia	3	4	4	2					1		1	
Scaevola paludosa	5	4	1	1	1		4		2	1	2	
Hypolaena exsulca	4	4	1	1	2		2					
Macarthuria australis	4				1		3	2			1	
Monotaxis grandiflora	4			2	1	2	2		1			
Haemodorum spicatum	5		1	1	1		1		1	1	1	
Calectasia cyanea	4		1		2		2		1	1		
Anigozanthos humilis	5		1	1	1	2	1	2			1	2
A. manglesii	4		2	1	2		1		2		1	
Acacia stenoptera	4		2	2	1			2	2		2	
Eriostemon spicatus	4	2	1	2	2			2			1	
Astroloma pallidum	4		1		1		5	3	2		2	2
Allocasuarina fraseriana	5		1	4	2	3	2	2	4	5		
Eucalyptus marginata		5	5	4	1	3			5	5	1	
Hibbertia huegelii	2	5	1	2	2	2	1					
Phlebocarya ciliata		4	1		2							
Pimelea sulphurea	2	5		1	2	5			1			
Opercularia vaginata	2	5	2	2	1	4	1		1		2	
Acacia willdenowiana		5	2	1			1					
Alexgeorgea arenicola	3	5		2	1	5	2		2	4	2	
Allocasuarina humilis	2	4			3	5	4		1			2
Lagenifera huegelii			4	2	1							
Kennedia prostrata	2		4	1	1				2	1	1	
Leucopogon propinquus	2		4	2	1	2	4	2	5		1	
Eryngium rostratum			3	2	1			4	5		2	
Dianella revoluta	4		3	2	1			5	4	3	4	
Xanthosia huegelii		2	3	2	2		1	4	1	1		
Hardenbergia comptoniana	3		4	4	1	2			5	4	1	2
Patersonia occidentalis	2	5		2	5		5		2			
Leucopogon conostephioides				1	3	4	3					
Eremaea pauciflora	2	2			3	2	4					
Synaphea spinulosa	2		1	2	1	5	5		1	3	1	
Acacia pulchella			2	1	3	5		2	1		2	
Waitzia suaveolens					1	4	2					4
Hakea lissocarpha						4				3	1	4
Calothamnus quadrifidus						4	1					3
Dryandra nivea	3		1	1	1	4		4	2		2	5
Banksia ilicifolia		3			1	1	5	2		1		
Scholtzia involucrata					3		5					
Drosera microphylla							5		2			
Calytri fraseri					1		4					
Jacksonia sternbergiana	2		1	2	1		1	5	2	3	3	2
Hakea prostrata					1	3		5	1	2		3
Acacia saligna	2		1	1		2	1	5	1	1		2
Hybanthus calycinus	3		1	1			2	4	2			2
Eucalyptus calophylla			2					5	2			
Pimelea rosea			1	1	1	1	1	5	1			
Acacia huegelii	2	2	1	2	2		1	4	2			
Hibbertia racemosa			2	3	3		1		4	1		
Haemodorum laxum							2		1	4		3
Phyllanthus calycinus			1	2	1				1			4
Stipa elegantissima	2		2	1	1	3	1		2		2	4
Lechenaultia linarioides											1	4

Table 2

Summary table of the major species composition of vegetation units from the *Dryandra sessilis—Calothamnus quadrifidus* complex (C), the *Olearia axillaris—Rhagodia baccata* complex (D), the *Tetragonia implexicoma* complex (E) and the *Cakile maritima* complex (F). Numerical values in the table are as Table 1.

Complex code:	C	C	C	D	D	D	D	D	D	E	F
Association code:	1	1	2	1	2	2	2	3	4		
Sub-association code:	a	b			a	b	c				
Number of samples:	6	4	13	4	8	1	5	5	1	5	5
Species											
Calothamnus quadrifidus	5	4	3	3	2						
Dryandra sessilis	5	4	3				1				
Grevillea thelemanniana	4	5	3								
Lomandra suaveolens	4	5	3								
Melaleuca acerosa	5	5	2	3	4		3	3			
Dryandra nivea	5	5	1								
Phyllanthus calycinus	5	5	1		2			4			
Acacia littorea	4	5	1								
Hibbertia hypericoides	5	3									
Xanthorrhoea preissii	4										
Hakea prostrata	5						1				
Schoenus grandiflorus	4		1		2			3			
Acacia rostellifera	4			2			5	3			
Conostylis candicans	4	2	1	3	2		2	3			
Stipa elegantissima	3	5	2		4						
Petrophile serruriae	2	5	1				2				
Kennedia coccinea	2	4	1								
Melaleuca huegelii	3	4	2				2				
Templetonia retusa		4	3		4		2				
Olearia axillaris	1	5	5	2	4	5	4	2	5		
Rhagodia baccata		4	5	3	3	5	2	4	5		
Pelargonium capitatum	1	4	4	4	5	5	4	3			
Hardenbergia comptoniana	1	2	4	5	2	5		3			
Callitris preissii				5							
Anthocercis littorea			1	3	1						
Acrotriche cordata				2							
Acanthocarpus preissii		3	3		5	5	4		5		
Lepidosperma gladiatum			1	2	4	5	3			2	
Acacia xanthina		2	1		5		2				
Poa poiformis			1		3						
Spyridium globulosum			3		3	5	2	3			
Myoporum insulare					2	5					
Atriplex cinerea						5					
Spinifex longifolius						5				2	
Acacia cyclops						5					
Scaevola crassifolia			2		2	5	1		5	2	
Clematis microphylla	1		2		2		4	3			
Dianella revoluta	2	2	1		1			4			
Eucalyptus gomphocephala			1		1			5			
Diplolaena dampieri							1	4			
Nitraria billardieri			1						5		
Threlkeldia diffusa			1						5		
Frankenia pauciflora					1				5	2	
Melaleuca cardiophylla			1						5		
Sporobolus virginicus										4	
Tetragonia implexicoma			1		1					5	
Isolepis nodosa										2	
Cakile maritima											5
Arctotheca populifolia											5
Spinifex hirsutus											5

Discussion

Havel (1979) noted that two factors appear of major importance in determining the vegetation pattern of the Coastal Plain: soil moisture and level of leaching (especially of soil iron). These factors are undoubtedly important—but seasonality of soil moisture and topographic variation are also important in determining vegetation pattern, e.g. Beard (1984). Havel (1979) also makes the important point that "vegetation is an integral part of the landscape in which it occurs. It is shaped by the landscape, and what vegetation is found at any one locality depends on the climatic, topographic and soil conditions at that locality".

In the case of the Coastal Plain, historical factors are also important and we propose the following scenario for the development of the present-day flora and vegetation. It is possible to visualise a total dune flora which oscillates through time e.g. species which are now confined to the Quindalup dune system were once common on the Bassendean dune system. As the sands of the Bassendean dunes became leached and Spearwood dunes developed seawards, only species tolerant of nutrient-poor conditions were able to survive. Some species, possibly excluded by competition from species of nutrient-rich habitats, are then able to colonise the newly vacant habitats. Species requiring nutrient-rich conditions, and those tolerant of salt spray and the pioneer dune ecosystem would then colonise the developing Spearwood dune system. This process is now being repeated between the Spearwood and Quindalup dune systems.

Table 3

Summary table of the major species composition of vegetation units from vegetation of wetlands. Numerical values in the table are as Table 1. *indicates mixed sward of *Cynodon dactylon* and *Paspalum distichum*.

Complex code:	G	G	G	H	H	H	H	H	H	I	I	I	I	I	I	I	J	J	J	K	L	L	L	L	M	N
Association code:	1	2	3	1	1	2	2	2	3	1	2	2	3	3	3	3	1	2	2		1	2	3	3		
Sub-association code:				a	b	a	b	c			a	b	a	b	c	d		a	b				a	b		
Number of samples	8	5	15	5	5	10	8	3	7	7	6	4	5	4	3	2	3	3	9	5	3	5	10	6	3	5
SPECIES																										
Typha orientalis	5	5		2	4	2	2	2	2	1	1															
Baumea articulata		5	5		2	1	2		1												2					2
Polygonum salicifolium		1	1	5	4	5			2																	1
Schoenoplectus validus			1	5	5		1																			
**Cynodon/Paspalum*	1		1		1	4	4	5		1		2	2								2	2	1			1
Eucalyptus rudis			1	2	1	5	5	2	2												2		1			
Melaleuca rhaphiophylla				2	2	5	4	4	5			5	5	4	5	3			5			2				1
Baumea juncea	1				2		1			5			5	5	5	5		2	2							
Centella asiatica			1	2	1		5			5	1		1						1	4		1	1			
Juncus kraussii	1									2	5	5	4					5	4	1	2					
Atriplex hypoleuca																		5	5	3						
Sarcocornia quinqueflora											2					3	5	5	5	3						
Melaleuca cuticularis																			2	5						
M. teretifolia				1	1										2	3					5	2		1		5
Deyeuxia quadriseta																					4		1	1		
Lepidosperma longitudinale														2						5	5	3	1	1		
Acacia pulchella																					4	3	2	1		
Viminaria juncea																					2	5	2			
Schoenus subfasicularis																							3	5		
Astartea fasicularis																						1	5	5		
Eutaxia virgata																							2	4		
Gahnia trifida							1				2	2	2			3			5	1						
Chara spp.															4										5	
Samolus spp.							1											4								
Ruppia spp.	2														5				1	2					5	
Bolboschoenus caldwellii	1				1																				5	
Polypogon monspeliensis		1			1		1			2	2	2							1	1						
Carex fasicularis					4																					1
Aster subulatus		2				1	1			2	2	2		5					1	1						1
Cotula coronopifolia		1								1	2	2	1	4												
Suaeda australis							1				2			2		2	2	4	2	2						
Melaleuca preissiana																					2	1	5			
Banksia littoralis																							4			

Table 4

Congruence between vegetation untis of the dryland dune systems and the structural formations, described by Specht *et al.* (1974). A '+' indicates the vegetation unit falls within a particular structural formation.

Floristic Vegetation Unit / Structural Formation	A 1 a i	A 1 a ii	A 1 b i	A 1 b ii	A 1 c	A 2 a	A 2 b	A 3	B 1 a	B 1 b	B 2	B 3	C 1 a	C 1 b	C 2	D 1	D 2 a	D 2 b	D 2 c	D 3	D 4	E	F
Banksia menziesii—B. attenuata—Casuarina fraserana—Eucalyptus todtiana Low woodland	+	+																					
Eucalyptus marginata—E.calophylla Woodland			+					+															
B. menziesii Low open-forest				+		+				+													
B. menziesii Woodland											+	+											
B. menziesii Low woodland					+		+																
E. marginata Low open-forest									+														
E. gomphocephala Low open-forest									+														
Dryandra spp.—*Hakea* spp. —*Casuarina* spp. Open-scrub													+										
Proteaceae—Leguminosae—Myrtaceae Open-heath																	+						
Proteaceae—Leguminosae—Myrtaceae Closed-heath														+	+						+		
Acacia rostellifera—A. cyclops—A. cochlearis Closed-scrub																			+				
Melaleuca laceolata—Callitris preissii Closed-scrub																+							
E. gomphocephala Woodland																				+			
Coastal Complex; Dune vegetation—Southern																		+				+	+

Table 5

Congruence between vegetation units of the wetland dune system and the structural formations described by Specht *et al.* (1974). A '+' indicates the vegetation unit falls within a particular structural formation.

Floristic Vegetation Unit / Structural Formation	G 1	G 2	G 3	H 1 a	H 1 b	H 2 a	H 2 b	H 2 c	H 3	I 1	I 2 a	I 2 b	I 3 a	I 3 b	I 3 c	I 3 d	J 1	J 2 a	J 2 b	K	L 1	L 2	L 3 a	L 3 b	M	N
Swamp complex	+	+	+							+	+	+	+	+	+	+									+	
Eucalyptus rudis—Melaleuca spp. Low open-forest				+	+	+	+	+	+																	
Halophytic complex																	+	+	+							
No described alliance																				+	+					+
Astartea fascicularis—Agonis parviceps—Melaleuca preissiana Closed-heath																							+	+		
Viminaria juncea Low open-shrub-land																						+				

As Fig. 2 demonstrates, vegetation at the coast, on the most recently formed dunes (Quindalup), is relatively species-poor (average of 11 species per 10 m² quadrat), whereas that of the oldest dunes (Bassendean & Southern River Systems) is species-rich (average of 40 species per 10 m² quadrat). Dry dune vegetation of the Quindalup dune system appears quite distinct from the vegetation of both the Spearwood and Bassendean Systems, which share some species.

Dry dune vegetation on the Bassendean soil association exhibits the greatest species richness for any single soil association, although the vegetation texture (pattern) is greatest in the Karrakatta and Cottesloe soil associations. Again this emphasises the difference between the younger Spearwood dune system and the older Bassendean dune system. The Spearwood dune system has a more diverse landform, containing a greater range of opportunity for vegetation texture to be expressed, compared to the older, less undulating landscape of the Bassendean dune system. Because the Bassendean Landscape is older there are greater opportunties for the factors promoting species richness, noted by Lamont *et al.* (1984), to operate.

Although limestone heath vegetation (basically the *Dryandra-Calothamnus* complex) contains elements of both the *Stirlingia-Oxylobium* complex and the *Olearia-Rhagodia* complex, it also has its own suite of identifying species, showing it clearly as transitional vegetation. Limestone heaths are found on the transition between Quindalup and Cottesloe soil associations, as well as forming the vegetation on limestone cliffs of the Cottesloe soil association.

Vegetation of the coastal plain wetlands also varies from west to east—primarily due to changing conductivity (salinity) of the ground water. This salinity gradient reflects a gradient of species richness. Highly saline wetlands of estuarine origin are species-poor, whilst low saline wetlands of freshwater origin are species-rich by comparison. The wetland communities with greatest species richness occur in the Bassendean dune system.

Wetland vegetation may also be arranged on a gradient of structural change—from sedgeland (swamp complex) to closed-forest (See Table 5). Structural attributes of the wetland communities are environmentally determined, with a variety of structural forms occurring in each soil association. The variation of structural form is strongly linked with the obvious vegetation zonation within wetlands, and has no geographical determination or significance.

Tables 4 and 5 show the relative lack of congruence between floristically based vegetation units, and structurally derived units. Several authors e.g. (Bridgewater (1978), Griffin *et al.* (1983)) have reported this from other vegetation types. This does not mean that either set of units is necessarily "better" than the other. There is evidence that vegetation classifications based on the "dominance type" do not reflect well the nuances of environmental variation (e.g. Griffin *et al.* (1983), Kirkpatrick and Glasby (1981)). For use in areas of great species and vegetation richness, floristically based methods appear the most appropriate to describe the full vegetation variation—an essential prerequisite to the development of adequate conservation plans.

Vegetation of the Swan Coastal Plain, being a mosaic of dryland dune systems, lakes, ephemeral swamps and riverine vegetation represents an important resource for future generations. It is important that adequate and representative samples of the coastal plain vegetation be conserved, to maintain the maximum representation of plant and animal species in this area. In this regard the difference drawn in this paper between richness of species and richness of vegetation texture is an important consideration in determining the adequacy of conservation measures. The conspectus and key should help to identify vegetation variation and help in the creation of an adequate and satisfactorily managed set of reserves, and provide a useful resource for educators in Biology and Environmental Science.

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Appendix

Key to vegetation units

To use this key it is important to select an area of vegetation approximately 10 metres square, which is not transitional in nature.

Unlike strictly dichotomus keys, there are six main points of entry (I-VI). Each point is defined by well recognised dominant species, or vegetation types. Within each of these six sub-keys are a series of statements. To use the key simply start at the first statement and move through each statement until a positive response is obtained.

Failure to reach an end point may be due to the vegetation selected being transitional in nature, or the vegetation having been particularly disturbed, and subject to invasion by exotic species.

It should, however, be possible to discover which of the six main groups the vegetation is *related* to, and work through the text description of each vegetation unit included in that group to find the nearest "fit".

As this key represents a new format to aid the recognition of vegetation units, the authors would appreciate comments from users on the degree of difficulty, or ease, in using the key in the field.

I

At least four of the following six species present: *Petrophile linearis, Conostephium pendulum, Bossiaea eriocarpa, Daviesia juncea, Hypocalymma robustum, Oxylobium capitatum*.
(Not as above—go to II)
**Eucalyptus gomphocephala*, or three of the following species present: *Hakea prostrata, Hardenbergia comptoniana, Dianella revoluta, Leucopogon propinquus* B.1.
*Three of the following four species present: *Patersonia occidentalis, Dasypogon bromeliifolius, Lyginia barbata, Tetraria octandra* A.1.
*three of the following four species present: *Eucalyptus calophylla, Eryngium pinnatifidum, Dianella revoluta, Dasypogon bromeliifolius* A.3
**Allocasuarina humilis* and/or *Acacia pulchella* present A.2

II

Four of the following six species present: *Banksia attenuata, Hibbertia hypericoides, Mesomelaena stygia, Allocasuarina fraseriana, Eucalyptus marginata, Xanthorrhoea preissii*
(not as above, go to III)
*Three of the following five species present: *Phyllanthus calycinus, Stipa elegantissima, Lechenaultia linarioides, Calothamnus quadrifidus, Hakea lissocarpha*. B.3
*Four of the following six species present: *Hardenbergia comptoniana, Alexgeorgea arenicola, Hibbertia racemosa, Leucopogon propinquus, Scaevola canescens, Acacia pulchella*. B.1
*None of the above species groups present. B.2

III

Heath or shrubland with two of the following species present: *Hibbertia hypericoides, Melaleuca acerosa, Dryandra nivea OR Dryandra sessilis OR* at least two of the following species present: *Olearia axillaris, Pelargonium capitatum, Rhagodia baccata, Hardenbergia comptoniana*
(If the conditions above do not apply go to (IV)
**Callitris preissii* present D.1
**Agonis flexuosa*—with *Dryandra sessilis, Hardenbergia comptoniana* present B.3
**Dryandra nivea* and *Melaleuca acerosa* or *Melaleuca huegelii* present with
—*Hakea prostrata, Acacia littorea, A. cochlearis* or *Templetonia retusa* present C.1
—*Acacia xanthina* present C.2
—neither of those combinations present C.2
**Acacia rostellifera;*
—with *Eucalyptus gomphocephala* present D.3
—without *E. gomphocephala* D.2
**Acacia cyclops* or *A. xanthina* with occasionally *Agonis flexuosa* present D.2
**Threlkeldia diffusa* or *Frankenia pauciflora* present D.4

IV

Foredune and Strandline communities
(If not as above go to V)
**Cakile maritima* present F
**Tetragonia implexicoma* present E

V

Melaleuca rhaphiophylla present
(If *M. rhaphiophylla* absent go to VI)
**Baumea juncea* with;
—*Gahnia trifida* and/or *Juncus kraussii* present I.3.a
—*Cotula coronopifolia* present I.3.b
—*Rupia polycarpa* present I.3.c
—none of the above species or combinations present I.3.d
—*Sarcocornia quinqueflora* present J.2.b
—*Eucalyptus rudis* present H.2.b
—*Carex fascicularis* and/or *Polygonum salicifolium* present H.1.b
**Sarcocornia quinqueflora* present J.2.b
**Atriplex hypoleuca* present I.2.b
**Polygonum salicifolium* with;
—*Schoenopletus validus* present H.1
—*Eucalyptus rudis* and *Paspalum distichum* or *Cynodon dactylon* present H.2.a
—*Centella asiatica* present H.2.b
—none of the above species present H.3
**Schoenoplectus validus* with;
—*Polygonum salicifolium* present H.1
—*Centella asiatica* present H.2.b
—*Baumea articulata* present G.3

VI

Various wetland sites, dominated by sedges or paperbarks
**Juncus kraussii* with;
—*Sarcocornia quinqueflora* present J.2.a
—*Melaleuca cuticularis* present K
—*Melaleuca teretifolia* present L.1
—none of the above species present I.2.a
**Baumea juncea* with;
—*Aster subulatus* present I.3.b
—*Centella asiatica* present I.1
—*Typha orientalis* present G.1
—none of the above species present I.3.d
**Sarcocornia quinqueflora* with
—*Melaleuca cuticularis* present K
—*M. cuticularis* absent J.1
**Melaleuca cuticularis* present K
**Melaleuca teretifolia* with;
—*Lepidosperma longitudinale* present L.1
—*L. longitudinale* absent N
**Typha orientalis* with;
—*Baumea articulata* present G.2
—*B. articulata* absent G.1
**Baumea articulata* present G.3
**Astartea fascicularis* with;
—*Melaleuca preissiana* and/or *Banksia littoralis* present L.3.a
—*Schoenus subfascicularis* present L.3.b
—*Viminaria juncea* present L.2
**Viminaria juncea* present L.2
*Open water,
Chara spp. present as submerged macrophytes M